

## STORMS IN JULY, 1913.

Severe storms were more numerous than usual, and they caused much damage to property and loss to crops. The storm of the 4th-5th in southern Minnesota and adjoining Wisconsin territory was one of the notable storms of the month. Near Pipestone, Minn., it is reported to have assumed tornadic proportions, and many buildings were wrecked, trees uprooted, animals killed, and several persons injured. This storm was also severe in the vicinity of St. Cloud, Minn., and at La Crosse, Wis. On the 8th squall winds occurred over the northeastern quarter of Illinois; trees, crops, and buildings suffered to a considerable extent, and 3 or 4 persons were killed; also hail injured crops over some areas. A severe thunderstorm, accompanied by hail, visited a few counties in west-central Illinois on the 15th; one person was killed by lightning. On the night of the 26th-27th a windstorm passed over northern Wisconsin; reports indicated that this storm may have been of tornadic character at some points. Houses and barns were blown down, many telegraph and telephone poles were broken off, and damaging hail fell over a large territory. On the 30th an electrical storm passed over Cairo, Ill., and there was a heavy downpour of rain, 2.56 inches falling in 1 hour and 31 minutes. Southern Minnesota and western Wisconsin were visited by a severe electrical storm on the 31st.

#### THE DEVELOPMENT OF WATER POWER IN WISCONSIN, AND THE RELATION OF PRECIPITATION TO STREAM FLOW.

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The utilization of the water-power resources of this country has become one of the greatest economic questions of the present time. Wisconsin has been endowed with resources which permit of extensive investigations and experiments in the field of water-power development, and this State has been one of the most progressive in this line of work. Wisconsin now is fifth in rank with other States in developed water power, having to her credit a total of 202,952 horsepower.

The importance of the rivers of this State as a factor in the distribution of its settlement and in its development industrially and otherwise has long been recognized. Statistics show that already a vast sum of money has been expended in the construction of dams, reservoirs, etc. The capital invested in the manufacture of paper alone amounts to \$13,325,000, and the money invested in public utilities and other industries which operate by water power would swell this figure enormously.

The following table shows the growth in the development of Wisconsin water powers:

	Horsepower
1870.....	33,700
1880.....	45,300
1890.....	56,700
1900.....	99,000
1905.....	124,400
1912.....	202,952

The annual saving represented by the power of 1912 over cost of an equivalent amount of steam power, computed at \$20 per horsepower, amounts to over \$4,000,000.

The Wisconsin rivers furnish an excellent field for the development of water power. They receive their run-off from territory within this State, and empty it into Lakes Superior and Michigan and the Mississippi River. The

sources of the streams lie principally on a divide consisting of a comparatively flat highland which crosses the northern part of the State. This plateau has an altitude ranging from 1,200 to 1,600 feet above sea level. The drainage is chiefly in a southerly direction to the Mississippi Valley and through Lake Winnebago and Green Bay to Lake Michigan. The aggregate fall in the main streams is from 350 to 800 feet.

The St. Croix, Chippewa, Black, and Wisconsin Rivers drain 70 per cent of the northern half of the State, and all empty into the Mississippi River. Lake Superior rivers drain only 9.3 per cent and those flowing into Green Bay the remaining 20.7 per cent.

The St. Croix River heads in the northwest corner of Wisconsin, about 20 miles from Lake Superior, at an elevation of about 1,000 feet, and flows southerly into the Mississippi River, forming part of the boundary between Minnesota and Wisconsin. Its total fall is 344 feet in 168 miles, of which the St. Croix Falls site with 50 feet fall is developed.

Chippewa River rises within 20 miles of Lake Superior near the Michigan border at an elevation of about 1,600 feet and flows southerly into the Mississippi River, falling about 850 feet in the distance of 270 miles. The main stream is formed by the east and west branches, and the Flambeau, Red Cedar, Jump, Yellow, and Eau Claire are tributaries. About 100 feet of the available fall is developed.

Black River rises in Medford County at an elevation of about 1,200 feet and flows southerly into the Mississippi River, falling some 600 feet in a distance of 140 miles. The falls at Hatfield and Ross Eddy and at some other sites, aggregating 170 feet, have been developed.

Wisconsin River rises in a chain of lakes near the Michigan boundary, at an elevation of about 1,600 feet, and flows southerly into the Mississippi River, falling 1,050 feet in about 400 miles. This is the most important water-power stream in the State, and on it are located some power plants which date back to the earliest settlement of Wisconsin. About 350 feet of the available fall is developed.

Rock River rises in Dodge County at an elevation of about 1,000 feet and flows southerly into Illinois. No power sites are shown on this stream, and those which appear to be commercially resourceful have been developed.

Milwaukee River rises in Fond du Lac County at an elevation of about 1,000 feet and flows southerly and easterly into Lake Michigan. It falls 400 feet in about 100 miles, of which 125 feet are developed.

Oconto River rises in Forest County at an elevation of about 1,500 feet and flows southeasterly into Green Bay and Lake Michigan. The Oconto falls 950 feet in 90 miles, of which 230 feet are developed; 190 feet of the fall occurs in the lower 33 miles.

Peshtigo River rises in Forest County at an elevation of about 1,600 feet and flows southerly into Green Bay and Lake Michigan. It falls 1,040 feet in 94 miles, of which about 50 feet are developed.

Menominee River rises in western Michigan and northern Wisconsin as the Michigamme and Brule, at elevations of about 1,600 feet. This river also flows southerly, forming part of the boundary between Michigan and Wisconsin, and empties into Green Bay and Lake Michigan. From the junction of the Michigamme and Brule the fall is about 700 feet in 100 miles, of which 210 feet are developed.

Manitowoc River rises in Calumet County at an elevation of about 1,000 feet. It falls 400 feet in 50 miles, of which 70 feet are developed.

Sheboygan River rises in Sheboygan County at an elevation of about 1,000 feet and flows southeasterly into Lake Michigan. Its fall is practically all developed.

Fox River rises in Columbia County at an elevation of about 800 feet and passes through Lake Winnebago at an elevation of 750 feet, which separates it into the upper and lower Fox Rivers, the lower Fox emptying into Green Bay and Lake Michigan. The fall in the upper Fox is about 35 feet in 110 miles and has no power opportunities. The lower Fox falls 170 feet, which is practically all developed.

Wolf River rises 25 miles south of the Michigan boundary at an elevation of 1,600 feet and flows southerly into the Fox River about 10 miles west of Lake Winnebago. The Wolf falls 820 feet in 160 miles, practically all concentrated in the upper 80 miles.

Montreal River rises in Iron County at an elevation of about 1,600 feet and flows northeasterly into Lake Superior. It forms part of the boundary between Michigan and Wisconsin. Its fall of about 1,000 feet occurs in 50 miles.

Bad River rises in Ashland County at an elevation of about 1,500 feet and flows northerly into Lake Superior. Its fall of 900 feet occurs in about 50 miles, and none of this is developed.

Bois Brule River rises in Douglas County at an elevation of about 1,000 feet and flows northerly into Lake Superior. Its fall of 400 feet occurs in 35 miles, none of which is developed.

Black River rises in Douglas County at an elevation of 1,000 feet and flows northerly, emptying into the Memadji River, which flows into Lake Superior. The fall of 400 feet occurs in 30 miles, none of which is developed.

Generally speaking, the hydrological and physical conditions in Wisconsin favor economic hydropower developments. The valleys, as a rule, have good breadth, the majority of stream beds are in rock, and the fall of the streams is not great, so that dams holding immense quantities of water are not difficult to construct. The possibilities of stream-flow regulation are also especially favorable on account of the large number of lakes on and near the headwaters of the different river systems, and most of them lie at altitudes of about 1,200 feet. Northern Wisconsin, including at least half of all the territory drained by the Wisconsin River, was originally timbered with many varieties of fine woods. Much of this timber was pine, and the first work of the lumberman in this territory consisted of cutting and manufacturing pine lumber. Much of this was done before the country had been penetrated to any great extent by railroads, and before the idea of transporting logs by rail had been evolved. Pine was easily floated and every stream became a highway for the transportation of logs to saw-mills. Most of the streams were rapid and the logs could be driven in them only in times of high water. The natural floods and freshets were not sufficient for carrying all the logs, and the construction of reservoir dams, used to store waters with which to produce artificial floods, began early. All of these dams were designed and used originally, not for the purpose of producing a uniform flow, but for the very opposite purpose, that of producing artificial floods, thus intensifying the irregularities of the streams.

Lumbering as an industry having greatly declined in Wisconsin during more recent years, the people became aroused to the fact that this State was not properly conserving its natural resources, and their attention was attracted to the possibilities of its water power. Engineers furnished statistics which showed that the streams of Wisconsin were blessed with approximately 1,000,000 horsepower. Business men began to realize that a vast amount of energy was going to waste in the rivers of Wisconsin, and if this energy could be harnessed and applied to useful purposes that great economy would be effected and a rich return would result. Through the untiring efforts of many public-spirited citizens proper State legislation was secured, which provided for the protection of public and private interests which seemed likely to be affected by the building of dams and reservoirs along the various streams, and this State now ranks fifth among all other States in utilized water power.

But it was found that some of the streams did not maintain a sufficient flow during certain seasons of the year and at other times there was a superabundance of water, and in some instance destructive floods. It was evident that some general plan must be devised in order to maintain a more regular flow of water during the different seasons of the year and during cycles of dry and wet years. The remedy of the situation seemed to lie in the construction of reservoirs in the headwaters which would to a considerable extent control the flow of the rivers below. It was also seen that the construction of numerous reservoirs would do much to mitigate the effect of severe floods which occurred frequently during the spring freshets. In making a survey of this problem it was found that nature had made provision for an economic construction of these reservoirs in a network of more than 1,000 lakes, the most of them being situated in the high-plateau region, thus laying an extensive foundation for reservoirs which could be made to serve as sources of supply to nearly all important streams.

The conditions in the headwaters of the Wisconsin River were found to be unusually favorable for storing water. At one point on this stream a dam 15 feet in height has now been constructed, giving a water storage fully 15 miles in length, spreading over 50 square miles. The Wisconsin Valley Improvement Co., which constructed this dam, is now operating 17 reservoirs in the headwaters of the Wisconsin River. These reservoirs control a drainage area of 1,200 square miles, with a reservoir service of approximately 62 square miles and storage capacity of 6,000,000 cubic feet of water. This service is given to 20 mills on the Wisconsin River above Kilbourn, with a total developed head of 335 feet. It is readily seen that the impounding of such an enormous amount of water during times of unusually heavy precipitation has an important effect in reducing the severity of floods, as well as furnishing a more regulated flow at all times.

Wherever the natural flow of the stream is to be utilized for power development, the minimum flow determines the design of the plant. Wherever storage is to be employed the annual yield of the drainage area is desired. If the observed stream flow or run-off for a long term of years is available, it is reasonably safe to depend on such records as a basis for water-power estimates without an investigation of the precipitation over the watershed. But long-continued records of run-off are seldom available, while the records of precipitation at many places cover a long term of years. By studying

records of precipitation and run-off made during periods for which both records are available on the stream itself and on contiguous watersheds, it is possible to estimate variations in flow which have occurred during the past, and consequently the variation which may be anticipated in the future. In studying the precipitation records it must be borne in mind that local conditions sometimes cause considerable variations in the amounts received, and averages should be drawn from observations made at several points on or adjacent to the drainage area. Such averages will usually represent the condition of rainfall to be expected over the drainage area, but occasionally for a particular month the amount that actually occurs may differ considerably from the average.

While the run-off of a stream is the direct effect of the precipitation that falls on its drainage area, there are many factors that may obscure and vary the relation between the two. Temperature, topography, geological conditions, vegetation, the presence of lakes and swamps, and other physical conditions affect and control the disposal of precipitation and the time at which it will appear in the stream flow. The influence of precipitation on the flow of streams is further dependent on the character of precipitation, its distribution over the watershed, and manner of occurrence. A steady rainfall, and one which is general over the watershed, falling at a time when the water in the main stream is considerably depleted, will furnish more satisfactory power than heavier showers which are local in character. The water-power engineer is especially interested in the

low-water flow of the stream, for that flow controls the constant power that can be maintained throughout the year. The total annual precipitation of course has not as great an influence on the low-water flow of the stream as its distribution throughout the year; and it is sometimes the case that in years when the total precipitation is below the average, a favorable distribution in its occurrence will give more satisfactory power than during some years when the precipitation is greater in amount but the distribution more unsatisfactory.

The foregoing remarks lead to the conclusion that precipitation records are invaluable to engineers in their efforts to solve problems in hydraulics. These records are often the basis upon which immense projects are planned. This fact should be given consideration in the selection of cooperative stations, to have them located so as to give as fair a distribution as possible over the watersheds, but at the same time serving other interests which are aided by climatological data.

The accompanying charts furnish information regarding the topography of the country and normal annual and monthly precipitation over the State. The principal streams are heavily outlined on the relief map, and power sites are indicated by means of small disks.

NOTE.—The normals of precipitation were obtained from stations having practically continuous records for the years 1891 to 1912, inclusive, and 47 stations were found available. At some stations a few months were missing, and estimated values were supplied based on a survey of the records of surrounding stations. Thus all stations afforded data for the same period of years.







